ROCKY 7 PROTOTYPE MARS ROVER: FIELD EXPERIMENTS IN THE MOJAVE DESERT, CALIFORNIA.

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Rocky 7 is a rover developed at the Jet Propulsion Laboratory to serve as a testbed for Mars rovers that would operate without the benefit of a lander for communications and imaging/navigational information. Rocky 7 was deployed at Lavic Lake (playa) from December 17-19, 1996 to test its abilities to navigate autonomously from waypoints defined in stereo images, to acquire and to dump soil samples, and to place a microscope imager against rock surfaces and acquire data. The rover completed over 300 m of traverses around bomb craters and ejecta, collected and purged several soil samples, and conducted close-up imaging of basalt boulders coated with caliche deposits. Independent position and orientation measurements were conducted for comparison to telemetry data received from Rocky and for construction of standard SPICE files. Some operations were conducted from the Jet Propulsion Laboratory using satellite communications. Rocky 7 will be deployed again in May 1997 at Lavic Lake with the addition of a Mössbauer Spectrometer. In these tests Rocky will cover a 2 to 3 kilometer traverse of a weathered basalt flow, an alluvial fan dominated by felsic rocks, and the edge of the playa. Plans and results are posted on http://wundow.wustl.edu/rocky7.

A key element of future Mars exploration, and one that has tremendous public appeal, is the presence of rovers on the surface that would operate autonomously and cover long distances, i.e., at least several kilometers. In effect, these vehicles would be doing field work, surveying sites, making key measurements, and even caching samples for return to Earth. Further, the promise of new views of the surface on a continuing basis, posted on the Internet using interactive browsers, has enormous potential for involving the public in the exploration and discovery processes. We have a great deal to learn about autonomous rover operations. Much will be learned from laboratory experiments. Experimental field deployments to Mars-like analog sites will also be crucial for understanding how to implement rover missions. Given the strong desire to return samples, it is highly likely that rovers will be key components of missions in the beginning of the next century. Given the short amount of time until rover operations on Mars, there is an urgent need to expedite the field deployment experiments. Two initial deployments using the Rocky 7 prototype rover (Figure 1) to Mars-like sites in the Mojave Desert are described in this paper, one conducted on December 17-19 1996 and one to be conducted on May 6-10, 1997. The experiments are designed to: (a) evaluate the ability of rovers to conduct autonomous traverses over distances of several kilometers (in contrast with Rocky 4 (Sojourner) which will always be in the field of view of the Pathfinder lander IMP imaging system), (b) maneuver instrumented robotic arms to acquire in-situ geochemical data and microscopic imaging as well as to acquire and cache samples, and (c) better understand how to conduct long-term mission operations at low cost.

Rocky 7 is a small rover built at the Jet Propulsion Laboratory, measuring 48 cm wide, 64 cm long, and 32 cm high. The wheel diameter is 13 cm. It is equipped with navigation CCD cameras in the front and rear of the rover chassis. These cameras are used both for navigation and imaging. The rover carries a sampling arm that can excavate to depths of 10 cm below the surface and can collect soil and small rock samples. In addition, the rover carries a stowable mast that when raised stands 1.4 m above the ground. A pair of cameras are mounted on the mast to acquire stereo images. In addition, a set of red, green, and blue filters are available to acquire color images of the scene. For the December tests, the mast also carried a closeup imager that provides 50 micron per pixel image resolution in color (LEDs for illumination). For the May tests, the closeup imager will be replaced with a Mössbauer Spectrometer. Rocky 7 uses a sun sensor, an accelerometer, and wheel encoders to estimate its position and orientation. The sun sensor is the critical sensor for long-range traverse.

A major element of Mars Rover Missions that was tested in December and will be further tested in May during the deployments is the ability of Rocky 7 to traverse autonomously a complex terrain with only waypoint information provided by uplink telemetry. The site chosen for the tests is Lavic Lake Playa and adjacent Pisgah Volcanic Field. The site for the December tests is on the northern side of the Playa, close to the contact with basalt flows. Basalt cobbles up to 20 cm in width litter the test site, along with several impact craters and associated ejecta fields generated by the Marines during strafing runs (the playa is an air-ground warfare site) (Figure 2). For the December tests, Rocky completed over 300 m of autonomous traverses using only waypoints to guide traverses. Soil samples were acquired and dumped. Two basaltic boulders placed as ejecta were sampled by placing the mast and its closeup imager onto the rock surfaces and imaging caliche deposits. Further, detailed rover location and orientation data were acquired during deployments. These data, together with Rocky 7 telemetry, will be used to generate SPICE files for comparison of where Rocky 7 thought it was as opposed to where it actually was located.

Unfortunately, for the December tests software and hardware problems precluded full tests of the ability of scientists located at their home institutions to define traverses and science measurements. For the May tests, we have selected an area on the southern part of the playa that has an eroded basalt flow and an alluvial fan composed of rock fragments of felsic composition. We also have panchromatic aerial photography and Thermal Infrared Mapper System (TIMS) images, and expect to have helicopter-borne images

acquired for the site in January. These data sets will be processed to simulate orbital and descent images. A small science team will be in place at their home institutions and will conduct the rover operations based on the data package. The intent is to traverse 2 to 3 km and make measurements at the basalt, playa, and fan sites. Further, a Mössbauer Spectrometer will be used to determine mineralogy of iron bearing phases and iron oxidation states of desert varnished surfaces of volcanic rocks. The spectrometer will be provided by Göstar Klingelhöfer, Technische Hochschule, Darmstadt, Germany.

Experiment plans (timelines and activities), along with detailed summaries of results, are available on the web (http://wundow.wustl.edu/rocky7), with relevant subsets of results to be published in appropriate engineering and scientific journals. Also, web pages will be used to disseminate results, including data. Measures of success include the ability to implement the operational plans in a manner consistent with the timelines, and the extent to which knowledge gained and documented during the tests are incorporated into planning and implementing actual Mars rover missions.

Figure 1. Rocky 7 prototype Mars rover obtaining a soil sample of the ejecta deposit of a bomb crater.

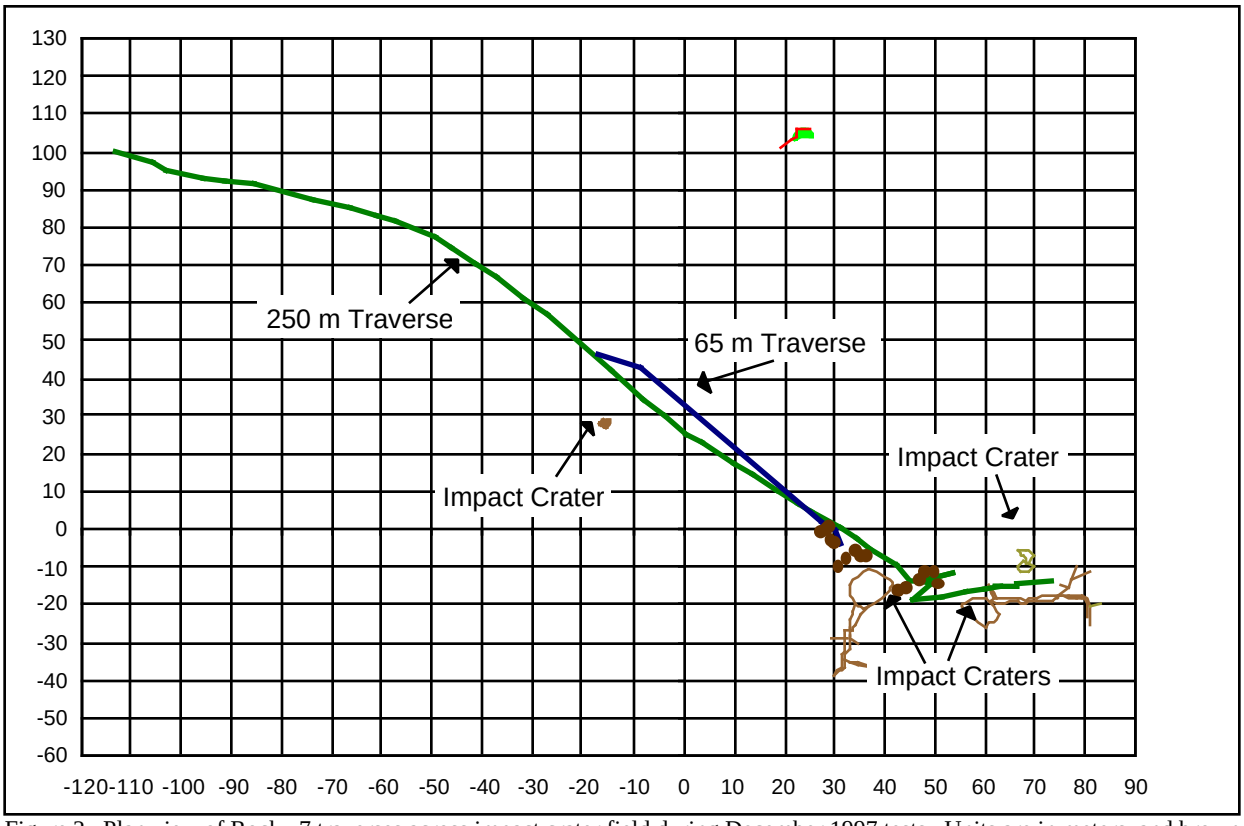

Figure 2. Plan view of Rocky 7 traverses across impact crater field during December 1997 tests. Units are in meters, and brown dots are manually-placed rock samples.